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Stochastic Inverse Modeling of Groundwater Flow and Environmental Tracer Transport: Baltenswil Case Study (Switzerland)

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Project Overview

Due to the large number of unknown parameters and their strong spatial variability, traditional groundwater model calibration is likely to yield **non-unique solutions** to the inverse problem, and thus unreliable results.

We cope with the ill-posedness of the inverse problem through an inverse stochastic approach, considering probability densities of parameters and analyzing statistics of the model results. This allows **quantification of uncertainty** in the model predictions.

The number of acceptable solutions – e.g. the set of input parameters capable to reproduce the measured data - can be reduced by **conditioning** the model parameters. Accounting for prior knowledge, e.g., by introducing environmental tracer data or geophysical data is a possible way to **minimize uncertainty** in the model predictions.

In the **present study** we are focusing on the **implementation of environmental tracer data** such as ^3H, ^3He, ^{85}Kr and SF_6 in the flow and transport model. This study is part of a joint project together with EAWAG, Dübendorf and IPB (University of Bern).

Environmental Tracers and the Role of the Unsaturated Zone

The release of environmental tracers into the atmosphere by nuclear power plants, bomb testing, and industrial processes dates back to the '50s (Fig.1).

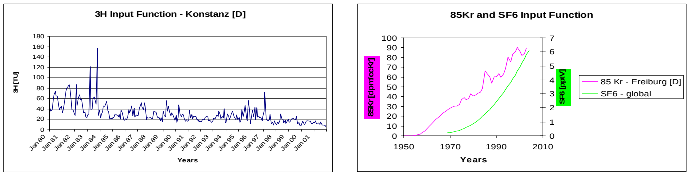

Figure 1: Atmospheric Input Function for ^3H, ^3He, ^{85}Kr and SF_6

Tracer dynamics in the **unsaturated zone** show different transport timescales for different tracers, resulting in a time lag or **delay** at the groundwater table . This delay Δt must be accounted for. It becomes more important with increasing thickness of the vadose zone (Fig.2).

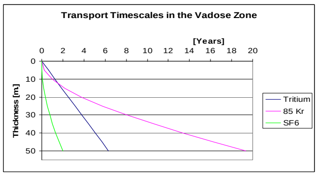

Figure 2: Time delay as a function of vadose zone thickness.
Water-bound tracers – like ^3H – move by advection following seepage water, gas tracers transport – like ^{85}Kr and SF_6 – is diffusion-dominated

Flow and Transport Modeling Results for the Baltenswil Case Study

The **Baltenswil site** is situated in the Aathal aquifer, a sandy gravel formation close to Zürich. The modeled area has extensions of 3x3 km² (Fig.3).

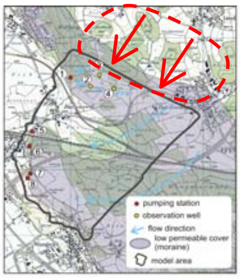

Figure 3: Baltenswil site

Stochastic Inverse Flow Modeling

Conditioning of the transmissivity field was performed by incorporating available head and transmissivity data using the **Sequential Self-Calibrated Method** (*Gómez-Hernández et al., 1997*), implemented in the code **INVERTO** (*Hendricks-Franssen, 2003*) (Fig. 4).

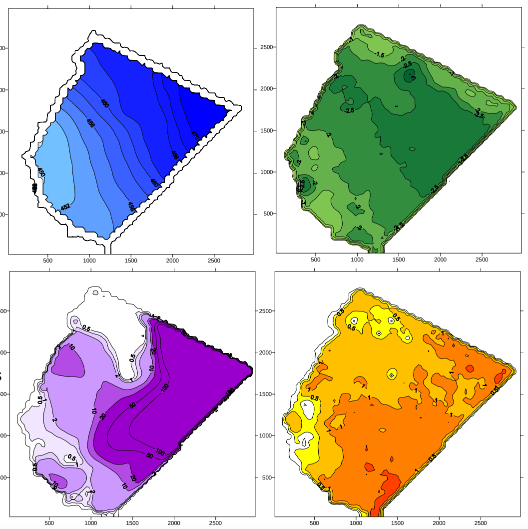

Figure 4: Top: Heads and Log10-transmissivity ensemble average. Bottom: Heads and Log10-transmissivity ensemble variance (100 realizations)

Deterministic Transport Modeling

For transport simulation, one transmissivity field realization was chosen from the ensemble. To account for the lateral inflow to the aquifer, the model domain was expanded (red dashed line in Fig.4). Simulations were performed for ^3H, ^3He, ^{85}Kr and SF_6 (Fig. 5).

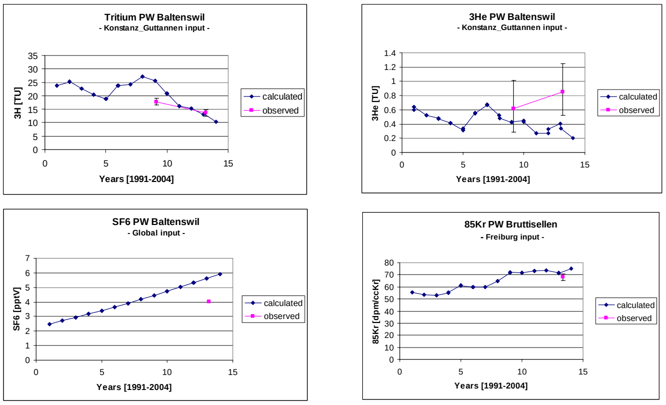

Figure 5: Modeling results vs. measured data

Conclusions

- The **importance of the vadose zone** in tracer transport is confirmed. The time delay is a key issue for a correct interpretation of concentration measurements in aquifers
- The **saturated zone** seems to play a minor role. Dued to the short residence time, no sensitivity to the transmissivity field, to preferential flow paths and to porosity was found
- The choice of the proper local tracer **input function** is essential for tracer transport simulations.

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